REMARKS

Applicant's attorney would like to thank the Examiner for the courtesy of a telephone interview held on May 22, 2009, in which the Examiner suggested helpful amendatory language for the claims. During the interview it was pointed out that applicant's invention avoids the need for a conventional Doppler shift processor to produce a spectral Doppler display. Instead, a user delineates a region of interest (ROI) in an ultrasound image where motion is present. The motion information of the spatially discrete pixels of the ROI is then arranged in a histogram of motion values, and the histogram is displayed as one temporally discrete (vertical) line of a spectral display. While this technique for displaying the spectral distribution of motion may have a different precision than a conventional spectral Doppler display which only samples the Doppler shift from a single spatial point (sample volume) in an image, it nevertheless gives the clinician a quick estimate of flow velocity variation in a ROI of a blood vessel.

The Goujon patent (US 5,941,826) is not doing this. What Goujon is doing is automatically computing the angle correction for Doppler measurements. As is well known, Doppler measurements of flow velocity are precisely correct when the direction of flow is in the direction of the transmitted ultrasound beam, that is, the direction is toward or away from the transducer and the Doppler angle is zero. As the direction of flow varies from this ideal, an error is introduced into the Doppler shift estimate. This is because the Doppler equation contains a cosine term of the angle between the beam direction and the flow direction. See col. 5, line 45 and col. 6, lines 5 and 6 of Goujon. When the direction of flow is perpendicular to (across) the beam direction, the Doppler angle is 90°, the Doppler response drops to zero and motion cannot be detected. This problem is compounded by the fact that many blood vessels of interest are generally parallel to the skin surface and therefore generally orthogonal to the transmitted ultrasound beams. For this reason, as Goujon states, ultrasound

systems try to consistently measure flow at a Doppler angle of 60° and then correct for this angle. As seen in col. 3, lines 41-51 of Goujon, what Goujon is doing is measuring the Doppler angle for a beam direction and blood flow direction, comparing the measured Doppler angle with an optimum value like 60°, then changing the beam steering to be at or close to an angle of 60°. The Doppler equation would then use a fixed angle correction for a 60° Doppler angle.

Some drawings can illustrate these principles. Enclosed Fig. A shows an ultrasound probe 10 with a transducer array 12 that is imaging blood vessels 90,92,94 beneath the skin 94'. I have drawn a triangular sector over the image area since cardiovascular probes usually perform a sector scan where all of the beams originate from a common point on the array. In this example it might be desired to do a spectral Doppler analysis of the point 96 in the blood vessels where the vessel 90 splits into vessels 92 and 94. Plaque often builds up at the junction of vessels and can cause a stenosis. The turbulence of blood flow velocities at this junction can be an indication that a stenosis is developing at this point.

The spectral Doppler exam is conducted as shown in Fig. B. An image 10 is acquired of the region of the body including the blood vessel. This can be a grayscale image of the tissue structure (referred to by Goujon as a "reflectivity image") or a grayscale image overlaid with a colorflow map of colors for the pixels which indicate relative velocity at each point in the image (referred to by Goujon as a "dynamic image.") In either case, the operator will place a Doppler beam line 22 over the image which the operator can swing from side to side over the image. This line 22 is aligned at each location with a beam direction of a beam used to form the image, meaning that the probe at the top of the image 12 can transmit Doppler beams along this line. On the line 22 are small cursors 16 which mark the location ("sample volume") where spectral Doppler signals are to be acquired. The operator can slide the sample volume cursors 16 up and down line 22 until it is aligned

with the point in the blood vessel where spectral Doppler signals are to be acquired. Inside the sample volume is a flow direction cursor 18 which can be tilted by the operator as if it were pivoting about the intersection of line 22 and cursor 18. The operator tilts the flow direction cursor so that it is aligned with the direction of blood flow, which is done by aligning the cursor 18 to be parallel to the vessel walls. The ultrasound system now knows to transmit Doppler beams down the line 22 and receive echoes back from the intersection point of line 22 and cursor 18 in the sample volume. The ultrasound system can also compute the angle between flow direction cursor 18 and the line 22, which in this example is about 75°. The ultrasound system will use this angle for the cosine term in the Doppler equation to correct the frequency estimates for a 75° Doppler angle.

A rapid sequence of beams is now transmitted down the beam line 22 and echoes are received in response to each beam from the sample volume. The beams are transmitted at a rate known as the pulse repetition frequency or PRF. A group of successive echoes called an ensemble are then processed by a fast Fourier transform processor (FFT) to produce a distribution ("bins") of Doppler shift frequencies from the sample volume. These frequencies are directly proportional to the velocities of blood flow at the sample volume. The bin values are then arranged in a line to form one vertical line of a spectral Doppler display. In col. 6, lines 57-59 Goujon refers to the spectral Doppler display of these vertical lines as a histogram. For instance in Fig. E it is seen that spectral line 10 ranges from frequency values which directly correspond to velocity values of zero cm/sec to 25 cm/sec. This process is repeated at a high rate, producing multiple spectral lines each second, each new one displayed next to the previous ones, which are shown as a scrolling or sweeping spectral display on the screen as illustrated at 20 the bottom of Fig. B.

Fig. C is a screen shot of an actual ultrasound display of a spectral Doppler exam. In this example the ultrasound image is

rectilinear (not sector) and has a parallelogram box 100 over it. The part of the image in box 100 is displayed with a color Doppler overlay, which is why it appears lighter in this black-and-white picture. The operator can vary the tilt angle of the parallelogram and the line through the center of the box 100 is the Doppler beam line 22 which varies in angle as the angle of the parallelogram is changed. At the upper right corner of the screen is a line of text which says that the Doppler angle is 60° for the box tilt shown in the image at this time. Along the Doppler beam line in the center of the vessel are the sample volume and flow direction cursors. It is at this point in the body where the Doppler data is acquired to produce the spectral Doppler display at the right side of the display.

Outside the color Doppler box 100 (for instance, to the left of the box) the image is just a grayscale image. You can see that the blood inside the blood vessel appears black, because the small blood cells return very little ultrasound echoes. The vessel walls above and below the lumen of the vessel are tissue which return much stronger echo signals, and thus the vessel walls show up as distinctly brighter in the display.

What Goujon is doing is automatically setting the location and tilt of his flow direction cursor. His first step in doing this is to have the ultrasound system automatically identify the walls of the blood vessel in a grayscale image as described in the passage spanning columns 1 and 2 of his patent. This process starts with the operator defining an "initial point" in the middle of a blood vessel. This is to the same effect as locating the sample volume as described above. From this cue, the ultrasound system then locates the vessel walls on either side of the initial point. This is done as illustrated in Fig. D, which is a blow-up of line 22 where it crosses the blood vessel in Fig. B. The small circles in Fig. D represent grayscale pixels along the line 22. Goujon calls this line of pixels a "histogram of the gray levels" in col. 1, line 66. Where the line of pixels crosses the lumen of the vessel

the pixels are black as indicated at 30 in Fig. D. Above and below the pixels 30 are pixels which are brighter. See the left side of Fig. C. Goujon now applies thresholds to the pixels and when a pixel above a threshold is encountered it is identified as being a vessel wall pixel. In the example of Fig. D, the brighter pixels 32 and 34 above and below the dark pixels would be identified as being the walls of the vessel. Goujon uses a number of lines which pass through the initial point Pi as shown in his Fig. 3. He finds the intersection Pl of each line with the vessel wall as illustrated in Fig. D. He then processes these identified points with the algorithms described in columns 9-11 to identify the directions of the vessel walls above and below his initial point Pi. Finally, he sets his flow direction cursor 13 ("inertial axis") parallel to the vessel walls as shown in Fig. 5. This "inertial axis" identifies Goujon's Doppler angle DA, which he can then use to do angle correction of Doppler velocities in his image. His preferred correction is to reset the transmit angle of the Doppler beam to be close to an ideal angle as described in col. 3, lines 41-62.

In the paragraph spanning columns 3-4 Goujon describes a spectral Doppler display such as Fig. E, which he characterizes as "a histogram showing the dynamic of the speeds as a function of time." Goujon says that his angle correction technique can be used to correct the scale of speeds of the Doppler spectrum (shown at the right side of Fig. E).

In the next paragraph Goujon says that his correction technique can be used to reset the angles of the Doppler lines to an "optimum" angle so that and accurate "instantaneous blood flow rate" can be measured. This can be done with a colorflow image as shown by color box 100 in Fig. C, where the color of each pixel across the section of the blood vessel inside the box spatially represents the instantaneous flow rate at that point in the vessel. A spatial integral calculation of all of the pixels in the vessel inside the box 100 would give you the average flow rate in that

section of the vessel. For example, the color values inside the vessel may range from 12 cm/sec to 20 cm/sec on the color bar adjacent to the colorflow image, but an integration of all of the pixel values across a section of the blood vessel may produce an average flow rate of 15 cm/sec at the instant that image frame was produced.

In column 6, lines 10-14 Goujon describes a grayscale image, which he calls a "reflectivity image." In lines 14-30 Goujon describes how a colorflow map ("dynamic image") can be produced, color-coded, and overlaid over the reflectivity image to produce a colorflow image as illustrated in box 100 of Fig. C. In lines 31-59 Goujon describes the basics of a spectral Doppler display, which he characterizes as an "alternative" to a grayscale or colorflow echographic image. He characterizes a spectral Doppler display as "a histogram showing the dynamic of the speeds as a function of time."

Nowhere does Goujon suggest taking the motion values of a plurality of <u>spatially different</u> points in an image to produce a spectral line or a spectral display, as claimed in the present invention. Goujon's spectral display is produced in the conventional way by receiving echoes from "injecting the successive pulses <u>at the same location of the medium</u>." (col. 6, lines 36-37) He then processes this echo data using the conventional Doppler equations given in col. 6, lines 5-6. For these reasons it is respectfully submitted that the enclosed amended claims are patentable over Goujon and the other cited references.

The amending language of the enclosed claims was derived from applicant's attorney's notes from the interview with the Examiner. If the Examiner believes that other language should be used, applicant's attorney would appreciate the courtesy of a phone call with the Examiner to produce mutually acceptable descriptions of the present invention.

In light of the foregoing amendment and remarks, it is respectfully submitted that this application is now in condition for allowance. Favorable reconsideration is respectfully requested.

Respectfully submitted,

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Fig. A

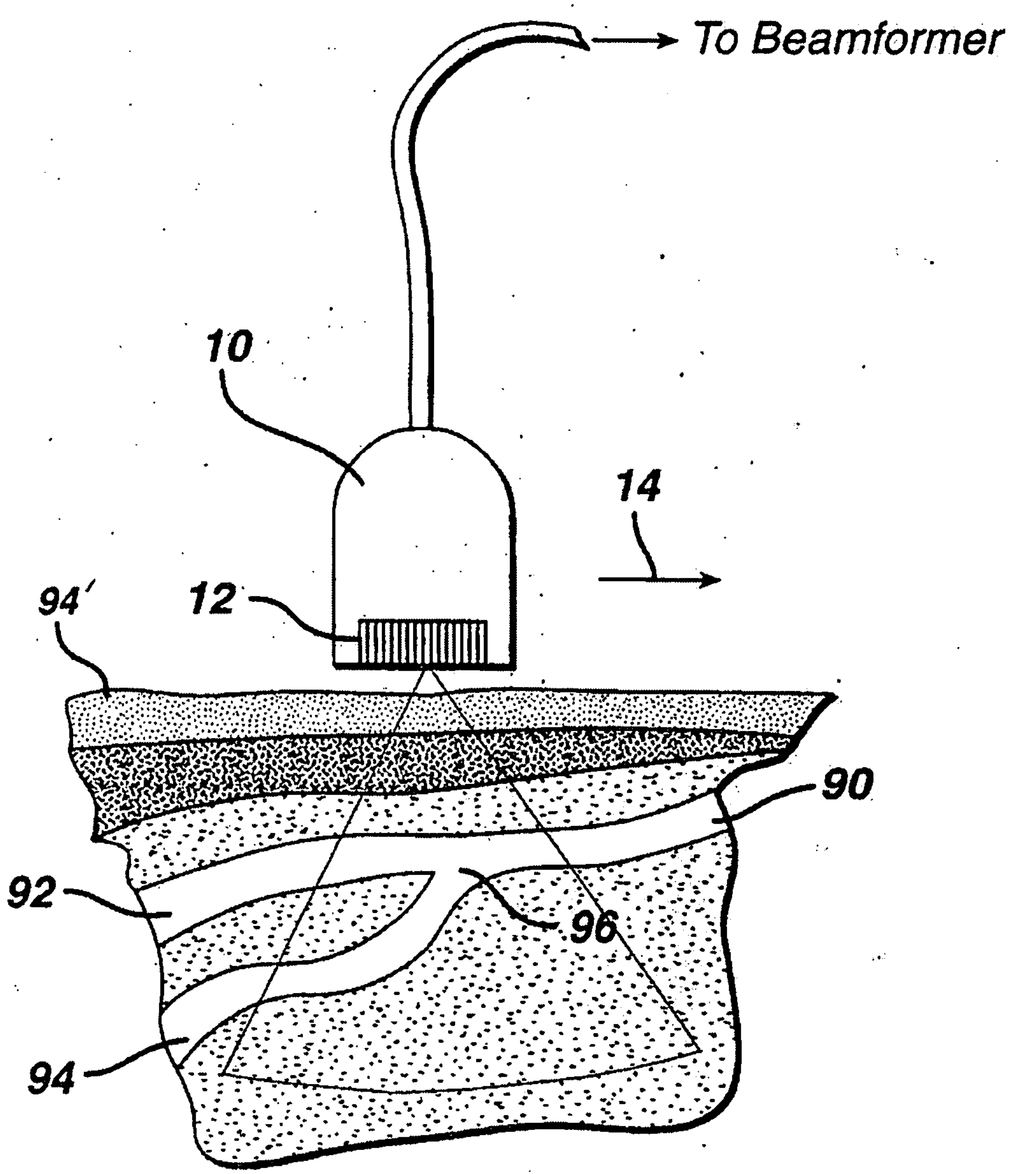
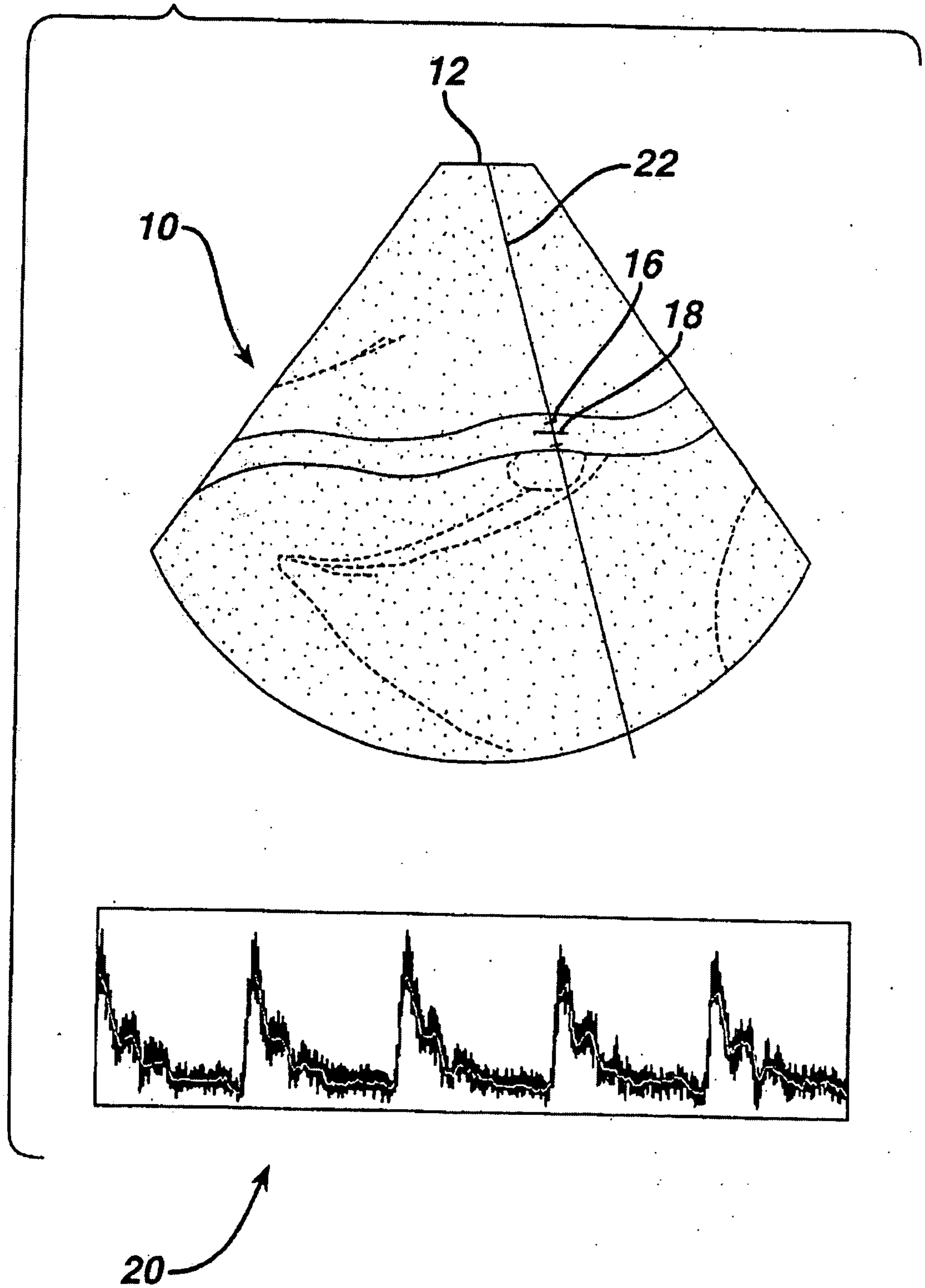


Fig. B



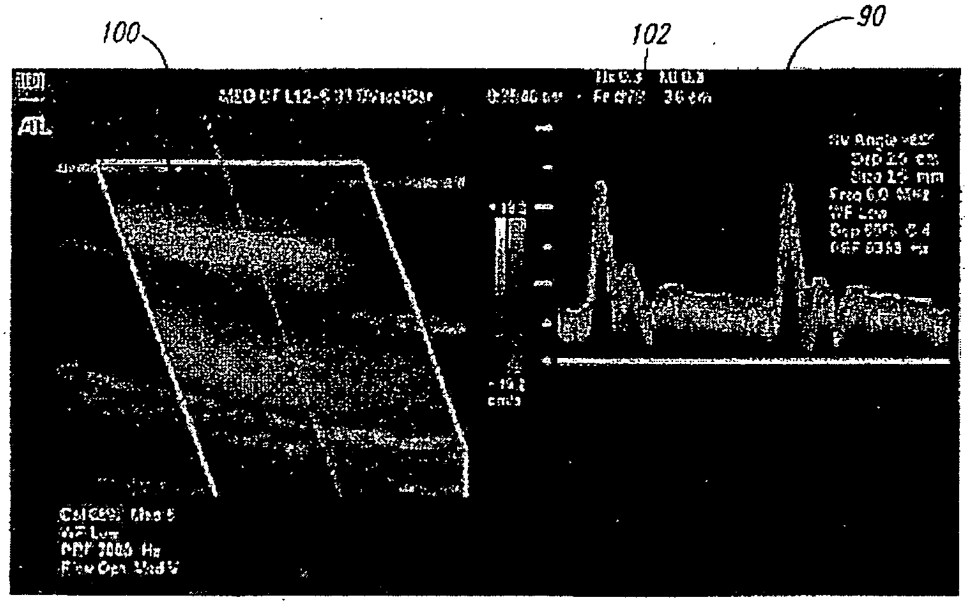


Fig. C

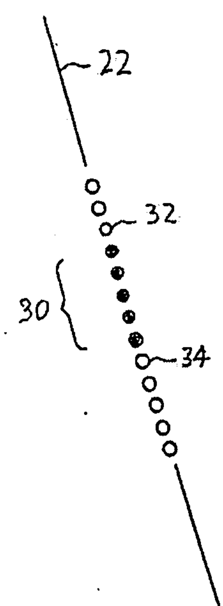


Fig. D

Fig. E PRIOR ART